IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
BEFORE THE BOARD OF PATENT APPEAL AND INTERFERENCES

In re the Application of: TI-11782A
William C. Choate, et al. Examiner: G. Barron, Jr.
Serial No.: 07/456,812 Art Unit: 222
Filed: 12/15/89
For: Method and Apparatus for Air-to-Air Aircraft Ranging

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Dear Sir:

Submitted herewith is Appellants' Brief, in triplicate, in Appeal from the final rejection of Claims 1-39. A copy of the claims on appeal is included as an appendix to the brief. Please charge the $630.00 filing fee, and any further fees, or credit any overpayment, to Deposit Account Number 20-0668. A duplicate of this transmittal sheet is enclosed.

Respectfully submitted,

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Dear Sir:

STATUS OF ALL CLAIMS

Claims 1-39 are provided in full in Appendix A. Claims 1-4, 10, 15, 17, 20-24, 30, 35, and 37 stand finally rejected and are the subject of the present appeal.

STATUS OF 37 CFR 1.116 RESPONSE

According to Examiner's Advisory Action mailed February 8, 1991, Appellants' response filed pursuant to 37 CFR 1.116 was considered but not deemed to place the application in condition for allowance.

SUMMARY OF INVENTION

Independent Claim 1 is illustrative of Appellants' invention and is reproduced as follows:

1. A method of determining the range between a target plane and a monitoring plane comprising the steps of:

generating model data corresponding to selected parameters describing flight path characteristics of the target plane;

passively collecting actual flight path data of the target plane;

generating an error measurement from said model data and said actual flight path data;

adjusting said model data to reduce said error measurement; and

calculating the range from said model data.

Independent Claim 10 includes a further limitation, exemplifying that found also in independent Claim 30, of "calculating a perturbation model, said perturbation model indicating a change in said model data which reduces said error measurement". Independent Claim 15 includes a different additional limitation, illustrative of that found also in independent Claim 35, of "adjusting the flight path of the monitoring plane in a direction optimizing ranging performance".

As said forth in Appellants' Specification, the methods and apparatus for passive ranging employ passive energy detection to correct errors between model data and actual flight path data when determining range between aircraft (Appellants' Specification page 1, lines 5-6; page 2, lines 1-13; page 4, lines 1-14). Active sensing is not utilized in Appellants' invention.

ISSUE PRESENTED FOR REVIEW

35 U.S.C. 103

Whether Claims 1-39 are nonobvious and therefore patentable over the teachings of the U.S. Patent No. 4,224,507 issued to

Gendreu, of tracking a moving target from a moving carrier using active sensors, or the teachings of U.S. Patent No. 4,320,287 issued to Rawicz, of tracking a moving vehicle using a Kalman velocity filter and active sensors, taken singularly or in view of U.S. Patent No. 4, 558,323 issued to Golinsky, which teaches passive ranging of an airborne emitter, or further in view of U.S. Patent No. 4,672,382 issued to Fukuhara, et al., which teaches a position measuring system for determining a vehicle's position by receiving radio waves emitted from satellites, or U.S. Patent No. 2,995,296 issued to Newell, et al., which teaches a target course predictor for a gun fire control system.

GROUPING OF THE CLAIMS

For the purpose of this appeal, the following claims are grouped together and therefore stand or fall together: 1-4; 10; 15; 17; 20-24; 30; 35; 37. In Paper No. 11, finally rejecting the claims at bar, Claims 5-9, 11-14, 16, 18-19, 25-29, 31-34, 36, and 38-39 were objected to as depending upon a rejected base claim, but would be allowable if rewritten in independent form including all of the limitations of the base claim and any intervening claims.

APPELLANTS' ARGUMENT

35 U.S.C. 103

The Office Action rejecting the claims on appeal urges that there is no patentable distinction in combining passive means for collecting actual flight data with means for generating error measurements based on a difference between generated model data and such collected data for calculating the range of a target plane from a monitoring plane. This contention is erroneous.

Practical Distinctions Between Active and Passive Ranging

The relevant ranging art divides into two categories: (1) those using signal processing to improve the performance of an

active sensor (e.g., radar) and (2) those estimating range from bearing measurements obtained with a passive sensor. Active ranging measures the two-way travel time of a pulse between an active sensor aboard a monitoring position and a target, i.e., radiant energy is transmitted towards a target followed by a reception of the echo. Because range is related to travel time by the speed of light, the elapsed time and any modulation of the transmitted signal provide considerable target data directly from the sensed signal, including bearing, range, and elevation. This type of sensing enables a target to locate the monitoring plane. Additionally, without signal processing, range errors obtained via an active sensor are on a par with those of the sought measurements.

Passive ranging, on the other hand, is frequently used for stealth, involves an entirely different approach to determining range, and employs passive sensors. Thus, passive ranging measures bearing to a target by sensing electromagnetic energy emitted by the target without emitting energy from a monitoring plane, i.e., there is no transmission of radiant energy towards a target, and the passive sensors aboard a monitoring plane are tuned to receive radiant signals that may emanate from the target. Because passive sensors can only detect bearing, range must be inferred from the temporal behavior of bearing as a target and the monitoring plane fly through air space. In fact, all target data is determined from inferences based only on the measurement of bearing of the target relative to the moving vehicle. This type of ranging, however, places stringent demands on any signal processing algorithm, as well as the passive sensing measurement system.

One source of difficulties for passive ranging lies in the direct relationship between bearing and range, namely, a single bearing measurement conveys no range information. This is not true with active ranging, where much information can be determined from the pulse sent out by an active sensor. Furthermore, there exists certain target trajectories, that although quite different, give similar bearing measurements. These target trajectories are quite difficult to distinguish when noise is present due to ill-condi-

tioning. "Ill-conditioning" means small changes in the received data cause large changes in the computed result. (Appellants' Specification, page 2, lines 12-18; page 2, line 26 to page 3, line 22).

Teachings of Gendreu

The Gendreu patent falls within the active ranging category (1), discussed above. Gendreu discloses active aircraft ranging apparatus employing active sensors such as radar, which enables a target to detect the monitoring plane. (Gendreu: FIG. 1; Col. 2, line 65-Col. 3, line 6, and Col. 5, lines 33-34).

Teachings of Rawicz

Rawicz teaches a straight-forward application of a Kalman filter to attenuate measurement errors and hence, improve range estimation accuracy for an active aircraft ranging apparatus employing active sensors such as radar. (Rawicz: Col. 2, lines 55-64, and Col. 3, line 66-Col. 4, line 5). Therefore, this reference also belongs in active ranging category (1), discussed above.

Teachings of Golinsky

The Golinsky reference falls within category (2) above for passive ranging and discloses a passive ranging algorithm derived from geometrical considerations (Golinsky: Col. 2, lines 65-68). He assumes the target is far enough away so that the target and the monitoring plane may be considered to fly in the same horizontal plane (Golinsky: Col. 2, lines 41-45), thereby formulating a strictly two-dimensional solution. Golinsky teaches direct solution from passively sensed input without use of any type of model.

Teachings of Fukuhara, et al.

The Fukuhara, et al. patent belongs to neither category discussed above, as it does not teach ranging. Instead, Fukuhara et al. teaches an improved position measuring system utilizing the global positioning system (known as "GPS") enabling a vehicle containing such system to determine its position based on radio waves

sensed by such system, wherein these radio waves contain navigational data emitted from satellites. Subsequent to the sensing of such navigational data, approximate values for the vehicle's position are computed by an initial estimated value computing means based on the navigational data detected. These approximate values are outputted as an initial set of estimated values and then fed to a convergent computing means which causes these initial estimated values to converge to the true position defined by the navigational data. (Fukuhara, et al.: FIG. 3, Col. 4, lines 23-37).

Teachings of Newell, et al.

The Newell, et al. patent technically falls into neither category as it relates to a target course predictor for a gun fire control system to enable a weapon to hit a target. Nevertheless, the system disclosed relies on an active sensor for input (Newell, et al.: Col. 1, line 53).

Patentability of Appellants' Claims in View of Applied Art

In the Office Action finally rejecting the claims at bar, the Examiner rejected independent Claims 1, 15, 20, and 35, as well as dependent Claims 2-4 and 21-24, as obvious over Gendreu or Rawicz in view of Golinsky. This rejection is based on an erroneous assumption; namely, that combining the passive sensing of Golinsky with the active ranging of Gendreu or Rawicz yields Appellants' claimed invention.

First consider the teachings of Gendreu which discloses the use of active sensors such as radar (Gendreu: Col. 1, lines 11, 15-23, Col. 2, lines 65-68, et. seq.) and states an "object of the present invention is to ... eliminate[s] a large proportion of the measurement noise, this noise being due to the conditions under which such measurements are normally made." (Gendreu: Col. 1, lines 55-60). Gendreu teaches correcting the errors introduced by the measurement noise present during active tracking of an object.

Gendreu fails to teach or even suggest use of, among other claimed aspects, "passively collecting actual flight path data of the target plane" or "adjusting the flight path of the monitoring

plane in a direction optimizing ranging performance". More important, however, is the fact the apparatus taught by Gendreu cannot work using actual flight path data which has been passively collected. The Gendreu reference specifically requires active input to operate, i.e., it requires information only obtainable from an active sensor (Gendreu: Col. 5, line 33-Col. 6, line 11, set out in full in Appendix B).

Next, examine the teachings of Rawicz which states: "sensory reference target position-reporting signals, typically radar return range, bearing and elevation parameters, are connected as inputs to the filter error node. In accordance with one aspect of the present invention, sensor reference errors from the input error node are converted to a target reference coordinate system (e.g., speed, course and angle of climb/descent)." (Rawicz: Col. 1, lines 36-43). Rawicz then continues by explaining how his invention uses this information. Thus, Rawicz also teaches a system which requires active sensing of information, such as target, bearing, elevation, speed, etc. It is readily apparent that Rawicz fails to teach or even suggest a system able to "passively collect[ing] actual flight path data" or "adjust[ing] the flight path of the monitoring plane in a direction optimizing ranging performance". Additionally, like Gendreu, the apparatus taught by Rawicz cannot work using actual flight path data which has been passively collected. The Rawicz reference specifically requires active input to operate, i.e., it requires information only obtainable from an active sensor. ("Sensor reference target signals (e.g., range, bearing and elevation) are connected as inputs to the filter error node" (Abstract)) (see also Rawciz: Col. 1, line 52-Col. 3, line 7 set out in Appendix C).

Additionally, Golinsky teaches direct solution from passively sensed input without use of any type of model. Therefore, Golinsky fails to teach or suggest "generating model data corresponding to selected parameters describing flight path characteristics of the target plane;...generating an error measurement from said model data and said actual flight path data; adjusting said model data to reduce said error measurement; and calculating the range from said

model data" (as exemplified by Appellants' Claim 1).

Only through hindsight could the Examiner have reconstructed the references and reach, erroneously, a conclusion that the claimed invention would have been obvious in view of the applied references. Hindsight is not a proper criteria for the establishment of a proper case of obviousness. See In re Horn, 203 USPQ 969 (CCPA 1979). It is imperative for the decision maker to place himself back in time to when the invention was unknown, i.e., without the Appellants' disclosure at his side, and determine, in light of all the objective evidence bearing on the issue of obviousness, whether one having ordinary skill in the art would have found the claimed invention was a whole obvious under 35 U.S.C. 103. Panduit v. Dennison Mfg. Co., 774 F.2d 1082, 227 USPQ 337 (Fed. Cir. 1985), vacated, 475 U.S. 809, 229 USPQ 478 (1986), aff'd on remand, 810 F.2d 1561, 1 USPQ2d 1593 (Fed. Cir. 1987).

In rejecting claims under 35 U.S.C. 103, it is incumbent upon the Examiner to provide a reason why one having ordinary skill in the art would have been led to modify the prior art or to combine prior art references to arrive at the claimed invention. This reason or basis for combining or modifying the references as the Examiner has suggested must stem from some teaching, suggestion, or inference in the prior art as a whole or knowledge generally available to one having ordinary skill in the art. Uniroyal, Inc. v. Rudkin-Wiley, 837 F.2d 1044, 5 USPQ2d 1434 (Fed. Cir. 1988); In re Geiger, 815 F.2d 686, 2 USPQ2d 1276 (Fed. Cir. 1987): Ashland Oil, Inc. v. Delta Resins & Refractories, Inc., 776 F.2d 281, 227 USPQ 657 (Fed. Cir. 1985); ACS Hospital Systems, Inc. v. Montefiore Hospital, 732 F.2d 1572, 221 USPQ 929 (Fed. Cir. 1984); In re Sernaker, 702 F.2d 989, 217 USPQ 1 (Fed. Cir. 1983). In the present application, the Examiner has failed to point to anything in the prior art that suggests in some way a combination of either of the primary references with the secondary reference(s) in order to arrive at the claimed invention.

Additionally no rationale has been presented as to why an artisan would have been led by the references to arrive at Appellants' claimed invention. The Examiner stated in Paper No. 11: "It would

have been obvious to one of ordinary skill in the art at the time the invention was made to use passive means as taught in Golinsky instead of the active means disclosed by Gendreu or Rawicz for collecting actual flight data in order to avoid detection by third parties or the target plane." Appellants contend this statement only reflects a known and desirable benefit of passive ranging. This statement does not constitute a reason why one of ordinary skill in the art would want to combine a passive sensor as taught by Golinsky with active ranging systems such as those disclosed in Gendreu or Rawicz, particularly since the systems would then no longer function.

A 103 rejection based upon a modification of a reference that destroys the intent, purpose or function of the invention disclosed in the *references*, is not proper and the prima facie case of obviousness cannot be properly made. In short, there would be *no technological motivation* for engaging in the modification. To the contrary, there would be a disincentive. In re Gordon, 733 F.2d 900, 221 USPQ 1125 (Fed. Cir. 1984). In that case, the Federal Circuit observed that if the prior art filter-separator were physically inverted, as would be necessary to meet the claim limitation, the reference filter would become impenetrable and fluid would be trapped rather than separated.

Nowhere in Gendreu or Rawicz is there any teaching or suggestion that one should employ a passive sensor in the systems and methods disclosed by Gendreu or Rawicz. Furthermore, as is apparent, the Gendreu, Rawicz, and Golinsky references are not properly combinable. Assuming one tried to so combine these references as suggested by the Examiner, it is clear the systems and methods taught by Gendreu or Rawicz would not work; they depend on active input and are solving problems resulting from active sensing. In light of the above, it becomes quickly apparent the Examiner has failed to present a case of prima facie obviousness. It would not have been obvious to one of ordinary skill in the art to have combined a passive sensor reference (Golinsky) with the cited active sensor references (Gendreu and Rawicz) and in any event, the combination would not result in the invention claimed in Claims 1, 15,

20, and 35. Therefore, independent Claims 1, 15, 20, and 35 are not obvious over Rawicz or Gendreu in view of Golinsky, taken together or singly, and should be allowed.

Claim 2 depends from independent Claim 1 and further requires "said selected parameters include measurements of the target plane's velocity and position". This claim incorporates all of the limitations of Claim 1, the overall combination of which is neither shown nor suggested in any of the cited references. Therefore, the resultant combination is not obvious over Gendreu or Rawicz or Golinsky, taken together or singly, and should be allowed.

Claim 3 depends from independent Claim 1 and further specifies "said actual flight path information includes measurements of elevation and azimuth of the target plane relative to a predefined coordinate system". This overall combination is unique and is neither shown nor suggested in any of the cited references. Thus Claim 3 is not obvious over Rawicz or Gendreu or Golinsky, taken together or individually, and should therefore be allowed.

Claim 4 depends from independent Claim 1 and further includes "the steps of: determining an azimuth sighting error by subtracting a measurement of azimuth of the target based on said model data from a measurement of azimuth based on said actual target flight path data; and determining an elevation sighting error by subtracting a measurement of elevation of the target based on said model data from a measurement of the azimuth based on said actual target flight path data." This unique combination of features is neither shown nor suggested in any of the cited references. Therefore, the invention defined by Claim 4 is clearly not obvious over Rawicz or Gendreu or Golinsky, taken together or singly, and should be allowed.

Claim 21 depends on independent Claim 20 and further requires "said processing device comprises a plurality of processing elements including microprocessors and arithmetic coprocessors." This claim incorporates all of the limitations of Claim 20, the overall combination of which is neither shown nor suggested in any of the cited references. Therefore, the resultant combination defined by Claim 21 is not obvious over Gendreu or Rawicz or Golinsky, taken

together or individually, and should be allowed.

Claims 22-24 each depend from independent Claim 20 and are allowable for reasons similar to those provided for Claims 2-4.

Claims 17 and 37 were rejected under 35 U.S.C. 103 as being obvious over Gendreu or Rawicz in view of Golinsky and further in view of Fukuhara, et al. In light of the above remarks, this rejection is also traversed. As noted above, Fukuhara, et al. discloses a position measuring system for a vehicle. The Fukuhara, et al. reference effectively teaches that the targets ("satellites") are broadcasting their exact locations, while the position of the monitoring plane is unknown, which amounts to the opposite problem from that solved by the Appellants' invention.

Furthermore, Claims 17 and 37 depend from independent Claims 15 and 35 and specify "further including the step of generating initial model data" (Claim 17) or "wherein said processing device is operable to calculate initial model data" (Claim 37). Fukuhara, et al. fails to teach or suggest either of these overall combinations. Additionally, not only does the hypothetically attempted combination of either Gendreu or Rawicz with Golinsky and Fukuhara, et al. still fail to meet Applicants' claimed structure or method as claimed in Claims 17 or 37, but furthermore nowhere in any of these references is such a combination suggested. Therefore, Claims 17 and 37 are not obvious over Gendreu or Rawicz or Golinsky or Fukuhara et al., taken together or singly, and should be allowed.

Independent Claims 10 and 30 were rejected under 35 U.S.C. 103 as being obvious over Gendreu or Rawicz in view of Golinsky and further in view of Newell, et al. In light of the above, this rejection is also traversed.

Applicants' invention requires "passively collecting actual flight path data of the target plane" (Claim 10) or "means for passively collecting actual flight path data" (Claim 30). As discussed above, neither Gendreu or Rawicz teach or disclose this aspect. Newell, et al. also fails to teach or suggest employing passive sensing of actual flight data. Instead it discloses a target course predictor for gun fire control requiring <u>active sen-</u>

sor input (Newell, et al.: Col. 1, line 53). (See also Newell, et al.: Col. 5, lines 30-41; Col. 6, lines 31-45, set forth in full in Appendix D).

Furthermore, in attempting to combine Gendreu (or Rawicz) and Newell et al. with Golinsky as the Examiner suggests, one still does not achieve the combination of features in Claim 10 or Claim 30 for the reasons discussed in connection with Gendreu and Rawicz above. Merely adding Newell et al. still fails to meet Claim 10 or Claim 30 because it also teaches active sensing. Additionally, not only does attempted combination of Gendreu or Rawicz with Golinsky and Newell, et al. fail to meet Applicants' structure or method claimed in claim 10 or Claim 30, nowhere in any of these references is a basis for such a combination taught, suggested, or inferred. Therefore, independent Claims 10 and 30 are not obvious over Gendreu or Rawicz or Golinsky or Newell et al., taken together or singly, and should be allowed.

Therefore, in light of the above, none of Applicants' claims under appeal are obvious over Gendreu or Rawicz in view of Golinsky, in further view of Newell, et al. or Fukuhara, et al., taken singly or together, and Claims 1-39 should be allowed.

CONCLUSION

Appellants claim a method and structure which is neither shown nor suggested by the prior art. Although the desirability of having a structure and method similar to Appellants' is great, the cited art, taken together or singly, fail to achieve Appellants' invention.

Accordingly, Appellants' claims are allowable. Therefore, Appellants request that the Examiner's final rejection of the claims on appeal be reversed.

Respectfully submitted,

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APPENDIX A

<u>The claims on appeal are as follows</u>:

1. A method of determining the range between a target plane and a monitoring plane comprising the steps of:

generating model data corresponding to selected parameters describing flight path characteristics of the target plane;

passively collecting actual flight path data of the target plane;

generating an error measurement from said model data and said actual flight path data;

adjusting said model data to reduce said error measurement; and

calculating the range from said model data.

2. The method of Claim 1 wherein said selected parameters include measurements of the target plane's velocity and position.

3. The method of Claim 1 wherein said actual flight path information includes measurements of elevation and azimuth of the target plane relative to a predefined coordinate system.

4. The method of Claim 1, and further including the steps of:

determining an azimuth sighting error by subtracting a measurement of azimuth of the target based on said model data from a measurement of azimuth based on said actual target flight path data; and

determining an elevation sighting error by subtracting a measurement of elevation of the target based on said model data from a measurement of the azimuth based on said actual target flight path data.

5. The method of Claim 4 wherein said error measurement includes a mean squared sighting error determined as an average of

the sum of the squares of said azimuth sighting error and said elevation sighting error over a plurality of intervals at which actual target flight path information is collected.

6. The method of Claim 5 wherein said error measurement further includes a velocity penalty based on a deviation between an estimated velocity of the target derived from said model data and a predetermined nominal velocity.

7. The method of Claim 5 wherein said error measurement further includes an azimuth position penalty based on a deviation between said azimuth sighting error and a predetermined azimuth sighting error bandwidth.

8. The method of Claim 5 wherein said error measurement further includes an elevation position penalty based on a deviation between said elevation sighting error and a predetermined elevation sighting error bandwidth.

9. The method of Claim 5 wherein said error measurement further includes a maximum range position penalty imposed when the estimated range of the target plane derived from said model data is in excess of a predetermined maximum acquisition range.

10. A method of determining the range between target plane and a monitoring plane comprising the steps of:

generating model data corresponding to selected parameters describing flight path characteristics of the target plane;

passively collecting actual flight path data of the target plane;

generating an error measurement from said model data and said actual flight path data;

calculating a perturbation model, said perturbation model indicating a change in said model data which reduces said error measurement;

adjusting said model data in accordance with said perturbation model; and

calculating the range from said model data.

11. The method of Claim 10 and further including the step of deriving a second-order Taylor series approximation of an error measurement equation used to calculate said error measurement.

12. The method of Claim 11 wherein said step of calculating the perturbation model includes the steps of:

determining a perturbation direction which minimizes said second-order Taylor Series approximation of said error measurement; and

determining an optimum perturbation magnitude along said perturbation direction which minimizes said error measurement.

13. The method of Claim 12 wherein said step of determining said perturbation direction includes the steps of:

determining a gradient vector of the error measurement equation;

determining a matrix having elements which are the second derivatives of the error measurement equation with respect to said model parameters;

determining a perturbation vector such that said matrix multiplied by perturbation vector equals said gradient vector; and

defining a perturbation direction in the direction of said perturbation vector.

14. The method of Claim 12 wherein said step of determining an optimum perturbation magnitude includes the steps of:

defining lower and upper magnitude boundaries encompassing said optimum perturbation;

determining values of said error measurement equation at said lower and upper magnitude boundaries;

determining values of the derivative of said error measurement

equation at said lower and upper magnitude boundaries;

calculating a polynomial approximation of said error measurement equation;

calculating an intermediate magnitude at which a derivative of said polynomial approximation is equal to zero;

calculating a value of the derivative of the error measurement equation at said intermediate magnitude;

setting said lower magnitude boundary equal to said intermediate magnitude if said value of said derivative of the error measurement equation at said intermediate magnitude is negative;

setting said upper magnitude boundary equal to the intermediate magnitude if said value of the derivative of the error measurement equation at said intermediate magnitude is positive;

setting said optimum perturbation magnitude equal to said intermediate magnitude if said value of the derivative of the error measurement equation at said intermediate magnitude is equal to zero; and

setting said optimum perturbation magnitude equal to an average of said lower and upper magnitude boundaries if said lower and upper magnitude boundaries are within a predetermined range.

15. A method of determining the range between a target plane and a monitoring plane comprising the steps of:

passively collecting actual flight path data of the target plane;

generating model data corresponding to selected parameters describing flight path characteristics of the target plane;

adjusting the flight path of the monitoring plane in a direction optimizing ranging performance;

generating an error measurement from said model data and said actual flight path data;

adjusting said model data to reduce said error measurement; and

calculating the range from said model data.

16. The method of Claim 15 wherein said step of adjusting the flight path includes the steps of:

determining sighting vectors between the monitoring plane and the target plane at a plurality of time intervals;

calculating a sighting matrix W such that

$$W = (1/N) \sum_{n=0}^{N-1} \underline{w}_n \underline{w}_n T$$

where $\underline{w}_n$ is a sighting vector at time t_n and N is the number of time intervals over which the summation is calculated; and

adjusting the flight path of the monitoring plane in a direction given by an eigenvector corresponding to the smallest eigenvalue of matrix W.

17. The method of Claim 2, further including the step of generating initial model data.

18. The method of Claim 17, wherein said initial model data includes an initial target velocity v_T calculated as:

$$\underline{v}_T = [\langle \underline{u}_1, \underline{v}_0\rangle - \rho_0\beta \cos((\theta_D/2) + \phi)]\, \underline{u}_1 +$$

$$[\langle \underline{u}_2, \underline{v}_0\rangle - \rho_0\beta \sin((\theta_D/2) + \phi)]\, \underline{u}_2 +$$

$$[\langle \underline{u}_3, \underline{v}_0\rangle]\, \underline{u}_3$$

where:

$\underline{u}_1$, $\underline{u}_2$, $\underline{u}_3$ - *eigenvectors corresponding to largest, second largest and third largest eigenvalues of matrix W.*

$\underline{v}_0$ - *ownship velocity vector*

θ_D - *angle between* θ_0 *and* θ_i, *calculated as* $[12\lambda_2]^{\frac{1}{2}}$, *where* λ_2 *is the second largest eigenvalue of matrix W.*

ϕ - *angle between* $\underline{w}_0$ *and* $\underline{v}_r$, *where* $\underline{v}_r$ *is the relative velocity vector.*

19. The method of Claim 17, wherein said initial model data includes as initial target position $\underline{c}$ calculated as:

$$\underline{c} = \rho_0 \ (cos((\theta_D/2)\underline{u}_1 - sin \ (\theta_D/2)\underline{u}_2)$$

where:

$$\rho_0 = [-B-(B^2-AC)^{\frac{1}{2}}]/A$$

$$where \ A = \beta^2$$

$$B = \beta[\langle\underline{u}_2, \underline{v}_0\rangle \ sin \ ((\theta_D/2) + \phi) -$$

$$\langle\underline{u}_1, \underline{v}_0\rangle \ cos \ ((\theta_D/2) + \phi)]$$

$C = \mu_0^2 - \mu_T^2$ (μ_0 *and* μ_T *are the speeds of the ownship and target*)

$$and \ \beta = [(f^2 + s_1^2)/(t_1^2(1 + S_1))]^{\frac{1}{2}}$$

$$where \ S_1 = tan \ (\theta_1); \ S_2 = tan \ (\theta_2)$$

$$f^2 = [(t_1/t_2)^2 \ (1 + S_1^2)^2 -$$

$$2(t_1/t_2) \ (1+S_1^2) \ (S_1^2+(S_1/S_2))$$

$$+ \ (S_1^2+(S_1/S_2))^2] \ S_2^2/(S_2-S_1)$$

20. Apparatus for determining the range between a target plane and a monitoring plane comprising:

a passive sensor for collecting actual flight path data of the target plane;

a processing device for performing arithmetic calculations;

said processing device operable to generate model data corresponding to select parameters describing flight path characteristics of the target plane;

said processing device further being operable to generate an error measurement from said model data and said actual flight path data and to adjust said model data to reduce said error measurement in order to calculate the range from said model data.

21. The apparatus of Claim 20 wherein said processing device comprises a plurality of processing elements including microprocessors and arithmetic coprocessors.

22. The apparatus of Claim 20 wherein said processing device is operable to generate measurements of the target plane velocity and position.

23. The apparatus of Claim 20 wherein said receiver collects measurements of elevation and azimuth of the target plane relative to a predefined coordinate system.

24. The apparatus of Claim 20 wherein said processing device is operable to calculate an azimuth sighting error determined by calculating an estimated azimuth measurement based on said model data and subtracting said estimated azimuth from a measurement of azimuth based on said actual target flight path data, said processing device being further operable to calculate an elevation sighting error determined by calculating an estimated elevation of the target based on said model data and subtracting said estimated elevation from a measurement of azimuth based on said actual flight path data.

25. The apparatus of Claim 24 wherein said error measurement includes a means squared sighting error determined as the average of the sum of the squares of the azimuth sighting error and the elevation sighting error over a plurality of intervals at which actual target flight path information is collected.

26. The apparatus of Claim 25 wherein said error measurement further includes a velocity penalty based on deviation between an estimated velocity of the target derived from said model data and a predetermined nominal velocity.

27. The apparatus of Claim 25 wherein said error measurement further includes an azimuth position penalty based on the deviation between said azimuth sighting error and a predetermined azimuth sighting error bandwidth.

28. The method of Claim 25 wherein said error measurement further includes an elevation position penalty based on the deviation between said elevation sighting error and a predetermined elevation sighting error bandwidth.

29. The method of Claim 25 wherein said error measurement further includes a maximum range position penalty imposed when an estimated range of the target plane derived from the model data is in excess of a predetermined maximum range.

30. An apparatus for determining the range between the target plane and a monitoring plane comprising:

means for passively collecting actual flight path data of the target plane;

means for generating model data corresponding to selected parameters describing flight path characteristics of the target plane;

means for generating an error measurement from said model data and said actual flight path data;

means for calculating a perturbation model, said perturbation model indicating a change in said model data which reduces said error measurement;

means for adjusting said model data in accordance with said perturbation model; and

means for calculating the range from said model data.

31. The apparatus of Claim 30 and further comprising means for calculating said error measurement from a second-order Taylor series of approximation of an error measurement equation.

32. The apparatus of Claim 31 wherein said means for adjusting said model data comprises:

means for determining a direction for perturbating said model data in which said second-order Taylor series approximation of said error measurement is minimized; and

means for determining an optimum magnitude along said perturbation direction which minimizes said error measurement.

33. The apparatus of Claim 32 wherein said means for determining said perturbation direction includes:

means for determining a gradient vector of the error measurement equation;

means for determining a matrix having elements comprising the second derivatives of the error measurement equation with respect to the model parameter; and

means for determining a perturbation vector such that said matrix multiplied by said perturbation vector equals said gradient vector.

34. The apparatus of Claim 32 wherein said means for determining an optimum perturbation magnitude includes:

means for choosing initial lower and upper magnitude boundaries encompassing said optimum perturbation;

means for determining a value of the error measurement

equation at said lower and upper magnitude boundaries;

means for determining a value of the derivative of said error measurement equation at said lower and upper magnitude boundaries;

means for calculating a polynomial approximation of said error measurement equation from said values of said error measurement equation and said values of the derivative of said error measurement equation at said lower and upper magnitude boundaries;

means for calculating an intermediate magnitude at which the derivative of said polynomial approximation is equal to zero;

means for calculating a value of the derivative of the error measurement equation at said intermediate magnitude;

means for adjusting said lower and upper magnitude boundaries, said lower boundary set equal to said intermediate magnitude if said value of the derivative of the error measurement equation is negative, and said upper magnitude boundary set equal to said intermediate magnitude if said value of the derivative of the error measurement equation is positive; and

said optimum perturbation magnitude set equal to a value of the average of said lower and upper magnitude boundaries if said lower and upper boundaries are within a predetermined range.

35. An apparatus for determining the range between the target plane and a monitoring plane comprising:

a passive receiver for collecting actual flight path data of the target plane;

a processor for generating model data corresponding to selected parameters describing flight path characteristics of the target plane; and

said processor calculating a flight path of the monitoring plane which optimizes ranging performance.

36. The apparatus of Claim 35 wherein:

said receiver collects data from which sighting vectors between the monitoring plane and the target plane may be determined at a plurality of time intervals;

said processor is operable to calculate a sighting matrix W such that

$$W=(1/N)\sum_{n=0}^{N-1} \underline{w}_n \underline{w}_n T$$

where $\underline{w}_n$ is sighting a vector at times t_n and N is the number of time intervals over which the summation is calculated; and

said processor is operable to calculate an eigenvector corresponding to the smallest eigenvalue of said matrix W, said eigenvalue giving an optimum direction for said flight path.

37. The apparatus of Claim 20 wherein said processing device is operable to calculate initial model data.

38. The apparatus of Claim 37 wherein said processing device is operable to calculate initial target velocity data v_T such that

$$\underline{v}_T = [\langle \underline{u}_1, \underline{v}_0 \rangle - \rho_0\beta \cos((\theta_D/2) + \phi)]\, \underline{u}_1 +$$

$$[\langle \underline{u}_2, \underline{v}_0 \rangle - \rho_0\beta \sin((\theta_D/2) + \phi)]\, \underline{u}_2 +$$

$$[\langle \underline{u}_3, \underline{v}_0 \rangle]\underline{u}_3$$

where:

$\underline{u}_1$, $\underline{u}_2$, $\underline{u}_3$ - *eigenvectors corresponding to largest, second largest and third largest eigenvalues of matrix W.*

$\underline{v}_0$ - *ownship velocity vector*

θ_D - *angle between* θ_0 *and* θ_i, *calculated as* $[12\lambda_2]^{\frac{1}{2}}$, *where* λ_2 *is the second largest eigenvalue of matrix W.*

ϕ - *angle between* $\underline{w}_0$ *and* $\underline{v}_r$, *where* $\underline{v}_r$ *is the relative velocity vector.*

39. The apparatus of Claim 37 wherein said processing device is operable to calculate initial target position data $\underline{c}$ such that

$$\underline{c} = \rho_0 \ (cos((\theta_D/2)\underline{u}_1 - sin\ (\theta_D/2)\underline{u}_2)$$

where:

$$\rho_0 = [-B-(B^2-AC)^{\frac{1}{2}}]/A$$

$$\text{where } A = \beta^2$$

$$B = \beta[\langle\underline{u}_2, \underline{v}_0\rangle \ sin\ ((\theta_D/2) + \phi) -$$

$$\langle\underline{u}_1, \underline{v}_0\rangle \ cos\ ((\theta_D/2) + \phi)]$$

$$C = \mu_0{}^2 - \mu_T{}^2 \ (\mu_0 \text{ and } \mu_T \text{ are the speeds of the ownship and target})$$

$$\text{and } \beta = [(f^2 + s_1{}^2)/(t_1{}^2(1 + S_1))]^{\frac{1}{2}}$$

$$\text{where } S_1 = tan\ (\theta_1);\ S_2 = tan\ (\theta_2)$$

$$f^2 = [(t_1/t_2)^2 \ (1 + S_1{}^2)^2 -$$

$$2(t_1/t_2) \ (1+S_1{}^2) \ (S_1{}^2+(S_1/S_2))$$

$$+ \ (S_1{}^2+(S_1/S_2))^2] \ S_2{}^2/(S_2-S_1)$$

APPENDIX B

The following is to be read in connection with Figure 1.

"A pulse radar (blocks 3, 4, and 5) is coupled to the antenna **1**. This is the measuring member proper which provides values for angular and range deviation or for range deviation. The antenna itself is of the monopulse type and has a even diagram of the "sum" type and two odd diagrams of the "difference" type in elevation and azimuth respectively to allow these measurement signal to be obtained. The unit **3** is formed by the transmitting and receiving circuits of the radar. On the basis of the video signals supplied by the receiver of unit **3**, unit **4** produces signals ΔS and ΔG for angular deviation. The purpose of unit **5** is to track the echo from the target, which is represented by a video pulse, in range. Measuring the out and back transit time of the pulse which is transmitted and then reflected by the target enables the range of the target to be estimated. A range-measuring marker in the form of a pulse is produced to represent the best estimate of range. The difference ΔR between the position of the echo and the range-measuring marker is made use of by the system in a manner which will be described further on in the specification.

The error measurements ΔS, ΔG and ΔR supplied by the radar are relative to a system of spherical coordinates in a reference frame related to the radar.

A unit **6** is responsible for converting the spherical coordinates into cartesian coordinates in the three-axis radar reference frame. It thus gives the three cartesian coordinates $\varepsilon'x$, $\varepsilon'y$, and $\varepsilon'z$ of the vector $\overrightarrow{DC}$ in relation to the radar reference frame (R, xr, yr, zr), D being the position estimated by the system and C the measured position of the target as seen from the focus of the antenna (FIG. 2).

Unit **12** then calculates the absolute components (εx, εy, εz) of vector $\overrightarrow{DC}$ in a reference frame (G, x, y, z) whose origin is

substantially the centre of gravity or the instantaneous centre of rotation of the carrier aircraft (FIG. 2). To do this, it makes use of the best estimate data ($\hat{\psi}$, $\hat{\theta}$ and $\delta\hat{\phi}$) on the angular attitude of the radar reference frame, which is supplied by the stablising unit **7** with the help of the inertial platform **8**.

<u>The absolute components calculated by unit **12** are transmitted to the simulator **17**</u> via a switch I_3 is normally in the transmitting state in position **1**. In position **2**, its purpose is to eliminate and cancel out the measured values applied to the simulator **17** when these values are clearly erroneous."

Gendreu, Col. 5, line 33 to Col. 6, line 11, emphasis added.

APPENDIX C

"FIG. 1 is a diagram depicting sensor and target vehicle coordinates for an illustrative vehicle tracking system of the present invention. ...

Referring first to the coordinate definition drawing of FIG. 1, there is shown a sensor reference coordinate system employed to locate a moving target vehicle presently located at a point P. <u>In the sensor coordinate frame of reference, the position p of the target vehicle is defined by a range from the sensor coordinate origin to the target (R); a bearing (β); and an elevation (ε) --</u> not shown for purposes of simplification only for the two dimensional FIG. 1 presentation, i.e., a conventional polar coordinate system.

There is also shown in FIG. 1 <u>a target or vehicle-based coordinate system defined by the speed (S) of the target</u>, i.e., the absolute value of the target velocity vector, <u>the course of the vehicle (θ), and the angle of climb or descent of the vehicle (ϕ)</u> -- also not shown for simplicity in the two dimensional diagram of FIG. 1.

It is observed for purposes of the underlying principles of the present invention that any maneuver of the target vehicle is most rapidly and accurately sensed and described with respect to the target vehicle coordinate system rather than in the sensor reference coordinate system. In this regard consider, for example, a rapid turn of the aircraft which results in a change of position from the point P to the position ′ of FIG. 1. The range and bearing coordinates R′ and β′ in the sensor reference coordinates will change only slightly responsive to the new vehicle velocity and the resulting position p′. These small changes in range and bearing (and also in elevation where such occurs) will be small since they may represent but a small percentage of the last reported range and bearing values; and may be masked or only slowly identified over system noise or other error factors because of the small percentage changes in their respective variables. Note, however, the rapid change in the course (θ) variable in the target reference system

which will thus accurately reflect the newly encountered target maneuver. Some reflection will show that other maneuvers such as vehicle acceleration/deceleration (speed (S) variable) or climb/descent (ϕ variable) or any combination of these, will similarly be most readily observed with respect to target vehicle parameters and not sensor reference coordinates.

Accordingly, the instant invention is directed to an improved target reporting Kalman filter apparatus which utilizes in part target vehicle referenced coordinates for moving vehicle position predicting. ...

With the above considerations in mind with respect to the target vis-a-vis sensor coordinate system, attention is now directed to a vehicle tracking and velocity filter of FIG. **2** which comprises an improved Kalman filter feedback structure adapted to in part include vehicle reference coordinates. The arrangement includes an input difference summing node **12** which receives measured target position information in sensor coordinates from a sensor **10**. Most typically, the sensor **10** may simply comprise a radar installation furnishing information as to the range (R), bearing (β) and elevation (ε) of a particular target then under consideration. The range, bearing and elevation sensor coordinates occur on a sampled data basis, corresponding to the information gathered during the last radar interrogation cycle. The information samples occur with a time interval T between successive samples corresponding to the inverse of the radar sampling rate.

At the output of the system, i.e., at the output of a summing node **19**, there is present all variables which represent the best current estimate of the position and motion of a subject target. The target is located in space in sensor or sensor-based (e.g., via any coordinate conversion) coordinates; but its motion is characterized in target coordinates. This best estimate information is applied to output utilization means **20** of any conventional type for processing and/or employing the information depending upon the environment of the composite apparatus."

Rawicz, Col. 1, line 52 - Col. 3, line 7, emphasis added.

APPENDIX D

"Yt -- Linear movement in horizontal range: The linear movement during the time of flight in the horizontal plane and in the vertical plane through the line of sight, due to relative motion, between own ship and target in the frame used by the fire control system (the horizontal line of sight component of target velocity), $Yt=\Delta Yt+jYt$.

ΔYt -- The generated line of sight component of target velocity due to changes in target bearing.

jYt -- Correction to ΔYt for changes in target course or speed.

$d(yt)$ -- Smoothed horizontal acceleration of target in plane of sight. ...

As already described, predictions are based on the assumption that the target will retain its present acceleration for ten seconds and that during this time its instantaneous velocity will vary from its present velocity according to this assumed constant acceleration. For any value of Tf less than ten seconds, the instantaneous future horizontal range rate of target movement will therefore be the algebraic sum of its present range rate (yt) and of its present range acceleration dyt multiplied by Tf, or $Yt+(dyt)Tf$. During this time, the average rate will be $Yt+1/2(dyt)Tf$.

The horizontal range distance (Rt) traveled by the target during Tf is the product of its average range rate and Tf or

$$Rt=(Yt)(Tf)+1/2Kd(yt)Tf^2."$$

Newell, et al.: Col. 5, lines 30-41 and Col. 6, lines 31-45, emphasis added.